

Mathematically-Based Algorithms for Film Digital Restoration

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Introduction

Since its invention, cinema has become an important media of popular culture, becoming part of our historical memory [1]. Unfortunately, films are subject to a fast decay and aging, especially when the conservation conditions are not appropriate. The decay process is irreversible, and the digitalization is becoming the most diffuse and suitable way to conserve and restore films [2].

Classic restoration software involves a significant human intervention and a work of supervision by qualified operators. Indeed, they require a frame-by-frame control and a further phase of manual cleaning. This workflow makes the restoration process expensive in terms of time and money, so that it can't be afford by small audiovisual archives.

The idea of our work is to provide a software which reduce the human intervention and that could be easily used even by small archives, being open source. Here we present, *DustRemover*, a semi-automatic software for digital film restoration.

Materials and Method

Film

The digital restoration was made on *"Isole nella Laguna"*. It is a documentary directed by Luciano Emmer and Enrico Gras in 1948, in which Diego Fabbri's voice describes the isles of Venice. It is a short film of 12 minutes, in B/W.

DustRemover

DustRemover is a digital filter which can be used to restore video frames affected by dust and little scratches. It is made by a series of different filters each of which is a plugin of a video manipulation framework called *VapourSynth*. The software consists of a core library written in *C++* and a *Python* module that allows the creation of video scripts. We have chosen this kind of framework because it is extremely fast and optimized for a great variety of machine architectures and, furthermore, the use of a *Python* module simplifies the workflow extension, such that it is easier to update and modify the underlying code [3] [4] [5].

As shown in Figure 1, *DustRemover* consists of three main phases: motion detection, noise detection and restore. Every phase has different parameters that can be set by the user due to the specific frames properties.

The workflow can be described as follow:

Motion detection is an automatic process which detects scene changes comparing the current frame with the previous and next ones. This step is fundamental to divide the film in scenes and to detect if in a scene there is movement. This is done with the parameter *dfactor*.

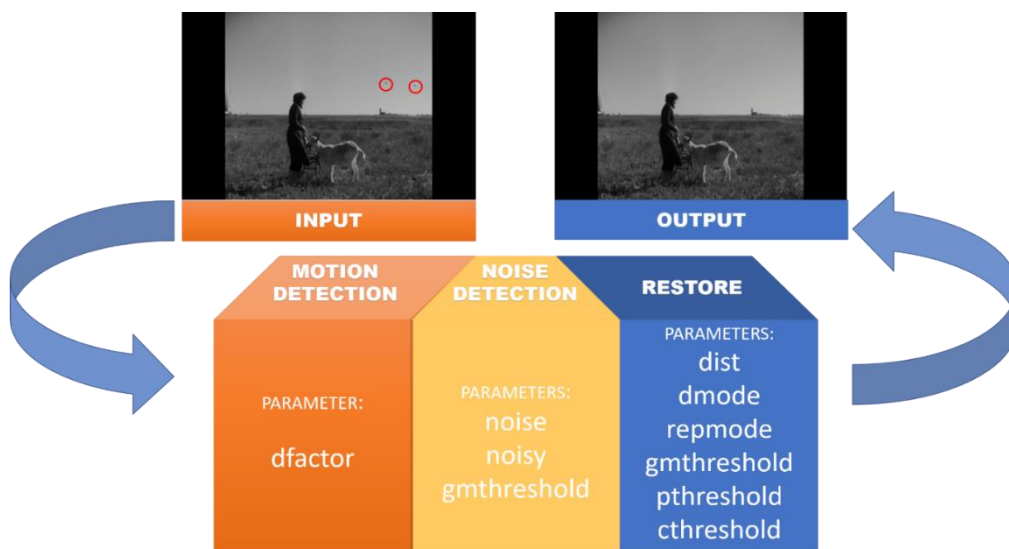


Figure 1 *DustRemover* workflow.

Noise detection computes the sum of absolute differences (SAD) between frames sub-sampled in 8x8 pixels blocks.

$$SAD = \sum_{i=1}^n |p_i - q_i|$$

Where p_i and q_i are the 8x8 pixels blocks of the current and previous/subsequent frames.

This phase is controlled by the following values:

- *noise*: defines the amount of noise contained in a frame using SAD.
- *noisy*: due to the *noise* in a block, divides the blocks in *motion block* (if there is movement) and in *noise block* (if there is just noise).
- As alternative to *noisy* is possible to use *gmthreshold* as value for the identification of a block as *motion block* due to its SAD value.

Restore is the last phase of the workflow and is the core of frames restoration.

This step is controlled by the following thresholds:

- *dist*: evaluates the differences between blocks identified as *motion blocks*.
- *dmode*: the higher is the value, the most accurate is the selection of the *motion blocks*.
- *gmthreshold*: is the same threshold of the previous phase, but here it figures out which frame has to be replaced.
- *repmode*: allows to choose between 24 different methods to restore frames.
- *pthreshold*: verifies how many blocks need to be restored working only on the luma plane.
- *cthreshold*: verifies how many blocks need to be restored working only on the chroma planes.

The **Input** of the workflow is a YV12 uncompressed video and the **Output** is a YV12 uncompressed video with the damaged frames restored.

Results and discussion

Parameters

DustRemover is implemented with default parameters that generally provides good results for dust and scratch removal. Despite this, default values aren't always the best choice for a total removal of dust and scratch so, a parameters selection is needed.

For the *dfactor* value, we kept it constant because the filter was performed on a single scene, but for the values of *noise* and *noisy* we found out that higher values (respectively of 26 and 28), are more effective than standard values, as Figure 2 shows.

	Default value	Selected value
dfactor	4	4
repmode	16	15
dist	1	1
gmthreshold	80	80
pthreshold	10	10
cthreshold	10	10
dmode	2	2
noise	10	26
noisy	12	28

Table 1 Parameters comparison.

During the restoration, we changed the default value of *repmode* from 16 to 15, because, among the 24 methods available, it is the most precise for dust and vertical scratch removal. This parameter is particularly critical during film restoration, because some methods, like the 24th introduce the *macro-blocking* effect as well as a horizontal line more pronounced on the background (see Figure 3).

The other parameters have been kept constant, in fact, if lowered, defects appear on the frame, if raised, particular improvements are not observed. Table 1 presents a comparison between the default values of *DustRemover* parameters and the most suitable ones for the analysed frames.

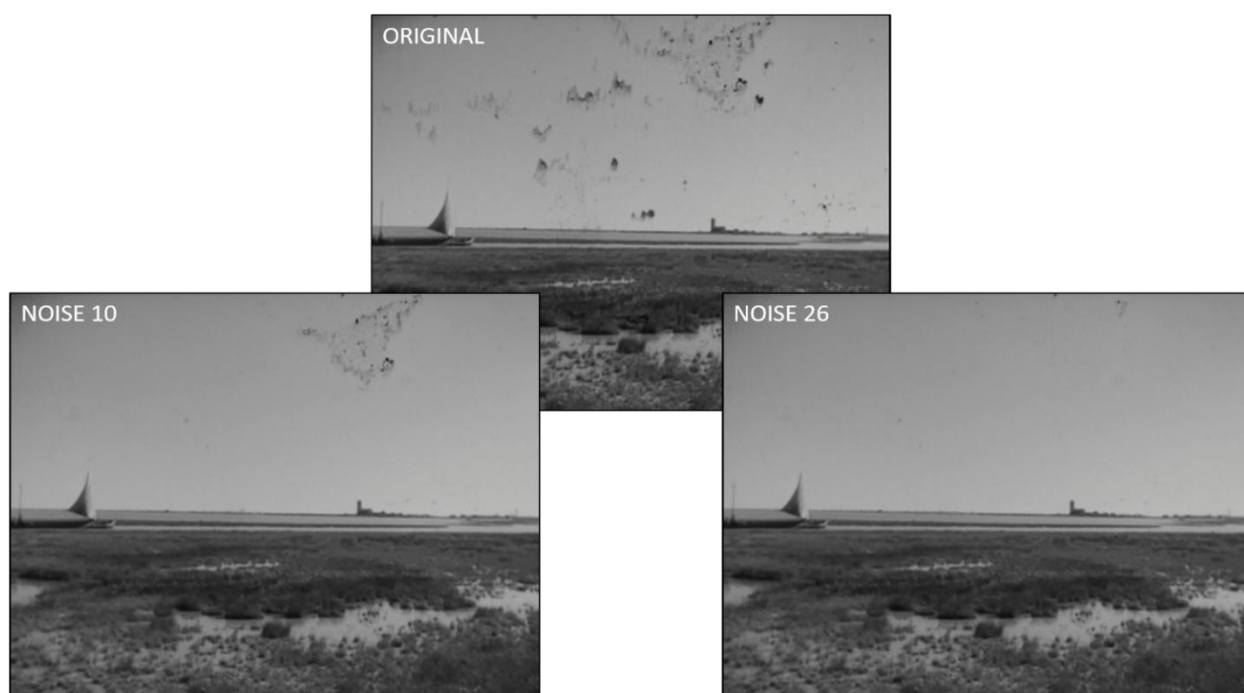


Figure 2 Comparison of different values of noise.



Figure 3 Example of macroclocking effect pointed out in the red rectangle.

DustRemover evaluation

The main limit of *DustRemover* is in the identification of scene changes, in fact if two following scenes respectively ends and begins presents a frame of *global motion*, it can't identify the scene change [4] [5]. Despite this, the resulting digital film restoration provides encouraging results, with an estimated removal of vertical scratches and dust of 70%.

An example of the effectiveness of *DustRemover* is shown in Figure 4, where is presented the restoration of a frame chosen from “Isole nella Laguna” using the parameters reported in Table 1.

As result of a general evaluation, it's possible to assert that *DustRemover* ensures an improvement of the visual quality. It determinates a satisfying removal of dust, a partial elimination of vertical scratches and an extensive cleaning of the images. In addition, the filter's execution is fast with a runtime around 6 – 8 milliseconds.

On the other hand, it must be taken into account that a supervision of the parameters of *noise* and *noisy* is needed, because an excessive increase can create loss of details, loss of edges and blur.

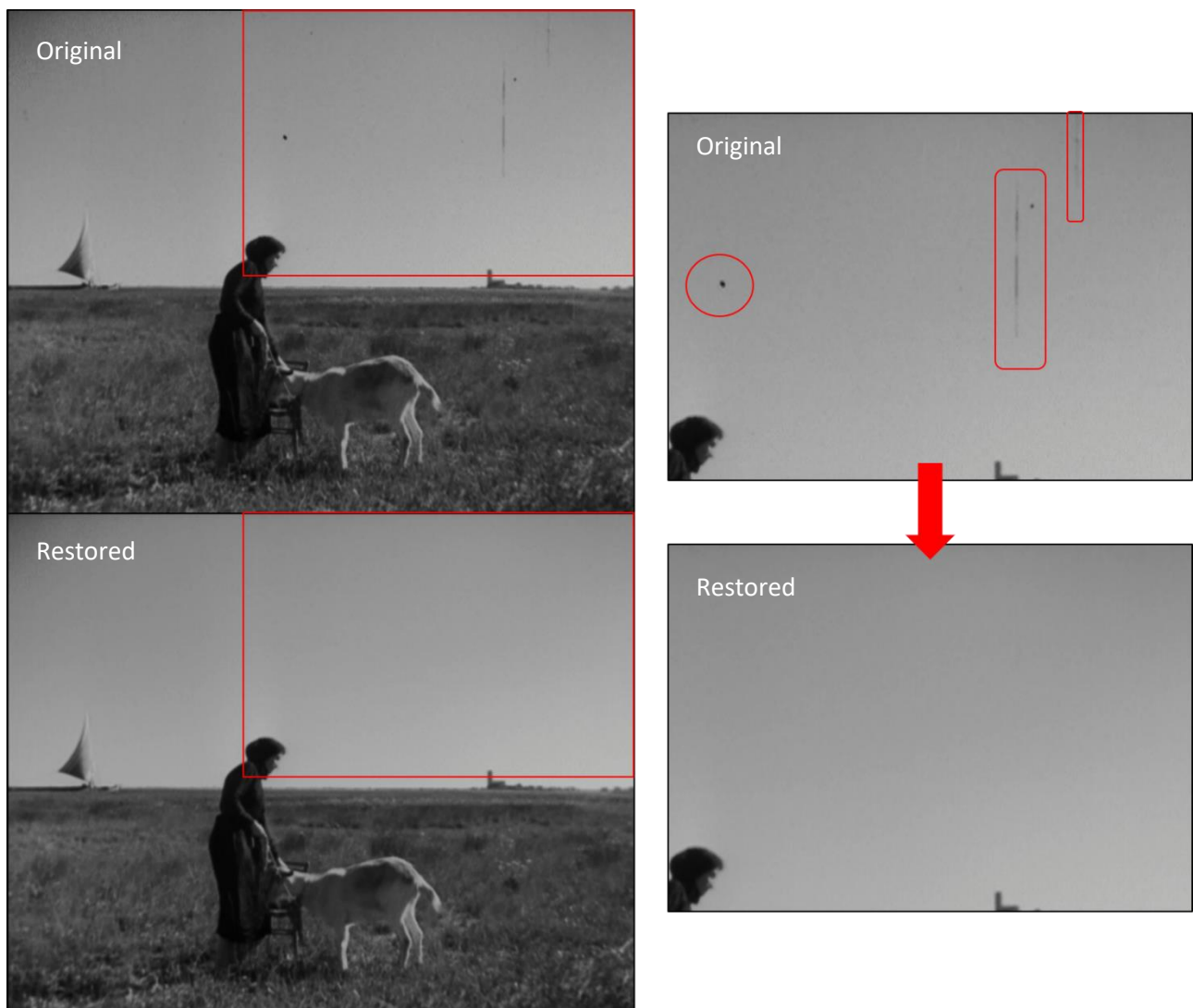


Figure 4 Example of *DustRemover* application.

Conclusion

In this work we presented the application and the evaluation of *DustRemover*, a semi-automatic software for digital restoration.

The evaluations made on “Isole nella Laguna” have pointed out that it removes dirt and sparkles, it reduces vertical scratches and noise and it ensures a general improvement of the visual quality of the frames.

It is open source and free, so one of its advantages is that even small audiovisual archives could afford it. Moreover, it needs a minor human intervention, shortening restoration time, even if a user supervision is required since parameters must be set case-by-case.

One aspect of the algorithm that could be improved is its ability to identify scene changes even when they occur between two scenes that respectively ends and starts with a motion block.

In addition, the next step of our study will be the test of *DustRemover* on color films in order to verify its performances.

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